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DEPARTMENT OF DEFENSE

U.S. ATOMIC ENERGY COMMISSION

[redacted]

Project

DANNY BOY

NEVADA TEST SITE

5 MARCH 1962

Final Report

LONG RANGE AIR BLAST MEASUREMENTS AND INTERPRETATIONS

J. W. Reed

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(21) Report on

PROJECT DANNY BOY.

PROJECT 1.1a

(6) LONG RANGE AIR-BLAST MEASUREMENTS AND INTERPRETATIONS.

(9) Final rept.

(10) by J. W. Reed.

(5) Sandia Corp[redacted]

Albuquerque, N[redacted] Mex[redacted]

(11) May 1962

FORMERLY RESTRICTED DATA

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ABSTRACT

Low-pressure air blast was measured for Project Danny Boy out to 240 km mainly in order to find the attenuation caused by the hard rock environment of the shot and to compare results with both nuclear and HE shots in other media. Nine microbarograph stations were operated. Various operational difficulties reduced the number of signal correlation points. Airblast pressures, both close-in and far-out, were appreciably smaller than expected from experience with underground HE shots. Transmission factors will not be calculated until final radio-chemical yield values for the shot are obtained.

CONTENTS

CHAPTER 1

INTRODUCTION

1.1 OBJECTIVES

Low-pressure air blast was measured to 240-km range on Danny Boy in order to:

1. Find the attenuation caused by bursting in a hard rock underground environment.
2. Check to see if Projects Stagecoach and Scooter results, that attenuation decreases with increased yield at constant scaled depth-of-burst (DOB) in desert alluvium, are also applicable in hard rock.
3. Find whether underground nuclear and high-explosive (HE) bursts give comparable air-blast effects.
4. Give further confirmation for sound-ray calculation techniques, as computed from rocket high-altitude wind instruments, when used at ranges beyond 100 miles.

1.2 BACKGROUND

Blast propagated to and beyond 160 km from the buried Teapot Ess shot gave pressure amplitudes little different from those that would have been expected from a surface burst of the same yield (Reference 1). Close-in high-pressure measurements showed considerable blast reduction caused by shot burial (Reference 2). If distant blasts from underground cratering or excavation shots are only slightly muffled, large Plowshare yields would cause considerable distant damage and adverse public reaction.

Distant blast measurements have been made on Plowshare Projects Stagecoach, Buckboard, and Scooter to develop understanding of this blast attenuation by shot burial at scaled depths which produce craters (References 3, 4, and 5). The blast transmission factor, defined here as the ratio of observed blast-wave pressure to that expected at the same range from a burst of the same yield in free air, increases with distance to long range. This has been demonstrated by every Plowshare microbarograph experiment (see Figure 1.1).

A comparison of Stagecoach and Buckboard data, for 20-ton HE bursts in desert alluvium and volcanic basalt showed that more distant air blast was transmitted from a hard rock environment at constant scaled DOB. Scooter, 500-ton HE, and Stagecoach bursts in alluvium showed more transmission for the larger yield from constant scaled DOB.

Each of these few measurements has rather large proportional errors caused by inconstant atmospheric sound propagation to great distances. Resultant transmission-factor uncertainties cause an uncertainty of more than an order of magnitude in establishing safe yield limits in extrapolating to large excavation projects. Of course, with careful selection of sites, season, and weather conditions, some very large cratering (or even surface-burst) projects may be conducted without significant damage, but if useful projects are to be pursued with optimum economy and minimum weather delay, then better understood and more accurate predictions must be available. To assure that no opportunity

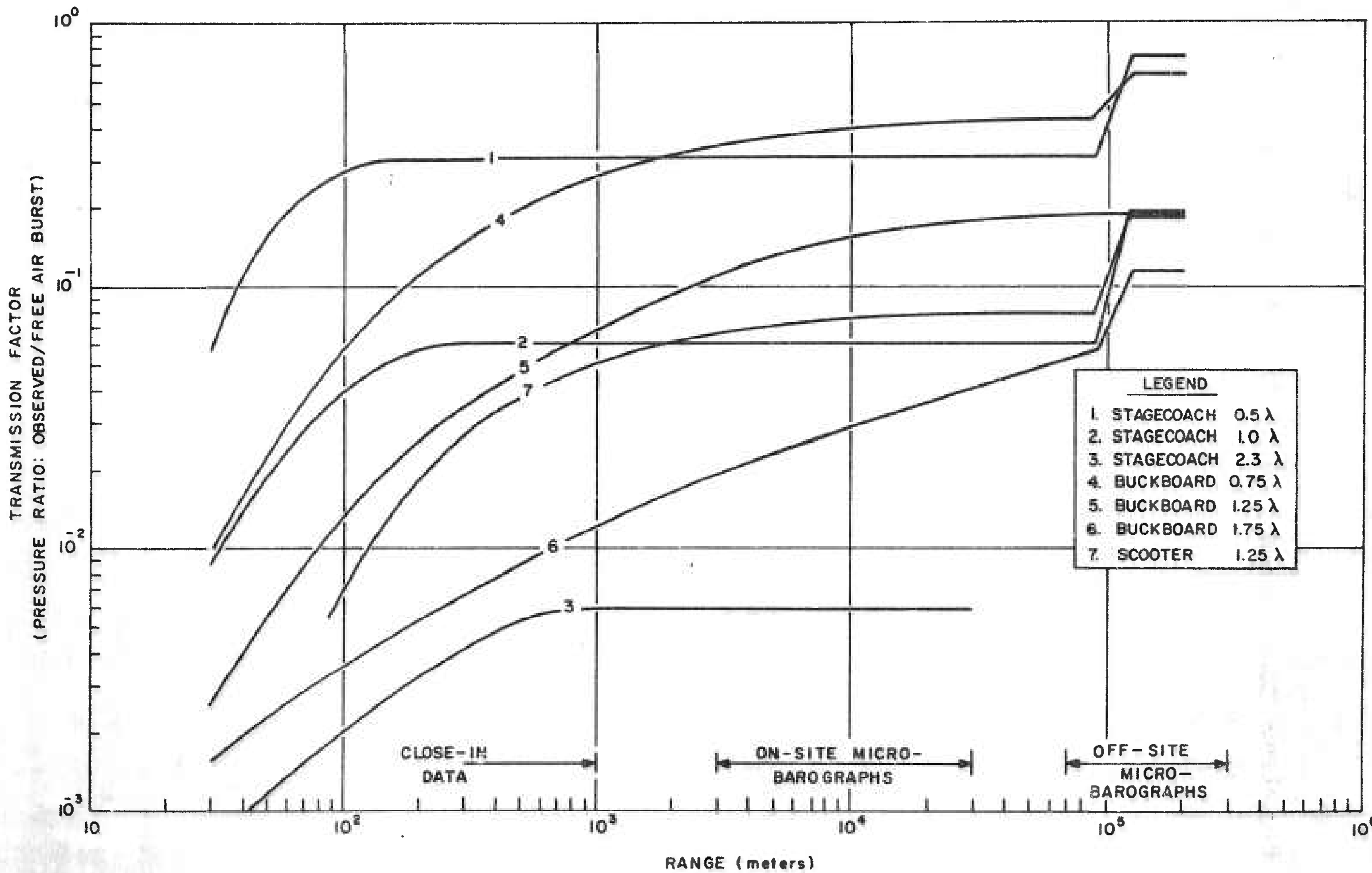

Figure 1.1 Air blast transmitted from Plowshare underground high-explosive shots at Nevada Test Site

is missed for refining blast-safety prediction techniques, every large Plowshare experiment should be monitored by distant blast-pressure observations.

Some further experience with air-blast transmission factors for underground bursts has been obtained from recording shots buried at depths which produce no cratering. The Plumbbob Rainier event and the Hardtack II underground tests, all burst in volcanic tuff (a soft, light, welded ash), appeared to emit significant air-pressure waves (Reference 6). There was no basis for comparing these signals with air bursts except by climatology, that is, the average seasonal propagation amplitude scaled from all previous Nevada tests (Reference 7).

In Operation Nougat, transmission experiments were performed on several shots but with limited success. Microbarograph participation has consistently been impaired by wind storms, as it also was on Project Gnome (Reference 8). The only results obtained so far are tentative and qualitative. Nuclear bursts buried deep in alluvium give much less air-blast transmission than those at equivalent depths in tuff. The one recording from a nuclear shot in tuff is not obviously inconsistent with estimated transmissions from Rainier and Hardtack II. Finally, the Hardhat burst in granite appears to have transmitted less air blast than was expected from Buckboard and tuff experience.

During 1960 Plowshare experiments at NTS, the first attempts were made to calculate ozonosphere blast propagations from rocket measurements of winds in the 30- to 45-km MSL layer. Rocket sounding techniques were developed for use during Hardtack high-altitude shots, but were never available for full-scale-test blast predictions at NTS. Results from Plowshare calculations were encouraging, but more experience is necessary before these predictions can be made with the confidence necessary for full-scale blast-safety requirements. These calculations have been verified many times for troposphere jet-stream-ducted blasts, but there are some added considerations for propagations along the extremely low-air-density, high-altitude ozonosphere paths which are not adequately understood.

1.3 THEORY

Air blast propagated from nuclear and HE bursts above ground has been documented in great detail in the strong-shock region. Some different opinions persist about overpressure-distance decay beyond the 300-mb region, but they are not of fundamental importance in long range prediction. It is here contended that the overpressure-distance curve calculated years ago at Los Alamos as IBM Problem M (Reference 9) provides a better reference standard at low pressures than the empirical curve used in "The Effects of Nuclear Weapons" (Reference 10). Actual nuclear-test data obtained at the distance of low-pressure measurements appear to be biased by refraction in the real atmosphere environment. They would not be duplicated in a truly

homogeneous atmosphere, if one of suitable dimension were available.

Grounds for this contention are found in data, as yet unpublished, from vertical propagations--parallel to atmospheric sound-velocity gradients and thus not bent by refraction--of blast from HE tests. First a series of 454-gram HE experiments was fired at Sandia Laboratory from 30 to 150 meters above a pressure gage array to show the appropriate pressure-distance curve extension to 7 mb. Then in DASA Project Banshee, three 227-kg HE shots were fired 24 km over White Sands Missile Range to give, among other things, unrefracted blast pressures at 40 microbars (μb). Both sets of data fall on a pressure-distance curve drawn from the end of IBM Problem M calculations at 25.5 mb, and with overpressure decaying inversely proportional to the 1.2 power of distance or

$$\Delta p \sim R^{-1.2}, \qquad (1.1)$$

where Δp is overpressure and R is distance. This recommended standard homogeneous atmosphere curve is shown in Figure 1.2.

A standard pressure-distance curve is scaled to different yields and gage-level ambient atmospheric pressures to predict a curve for a particular shot by applying the two equations

$$\Delta p' = \Delta p(p'/p) \qquad (1.2)$$

$$R' = R(W'p/Wp')^{1/3}, \qquad (1.3)$$

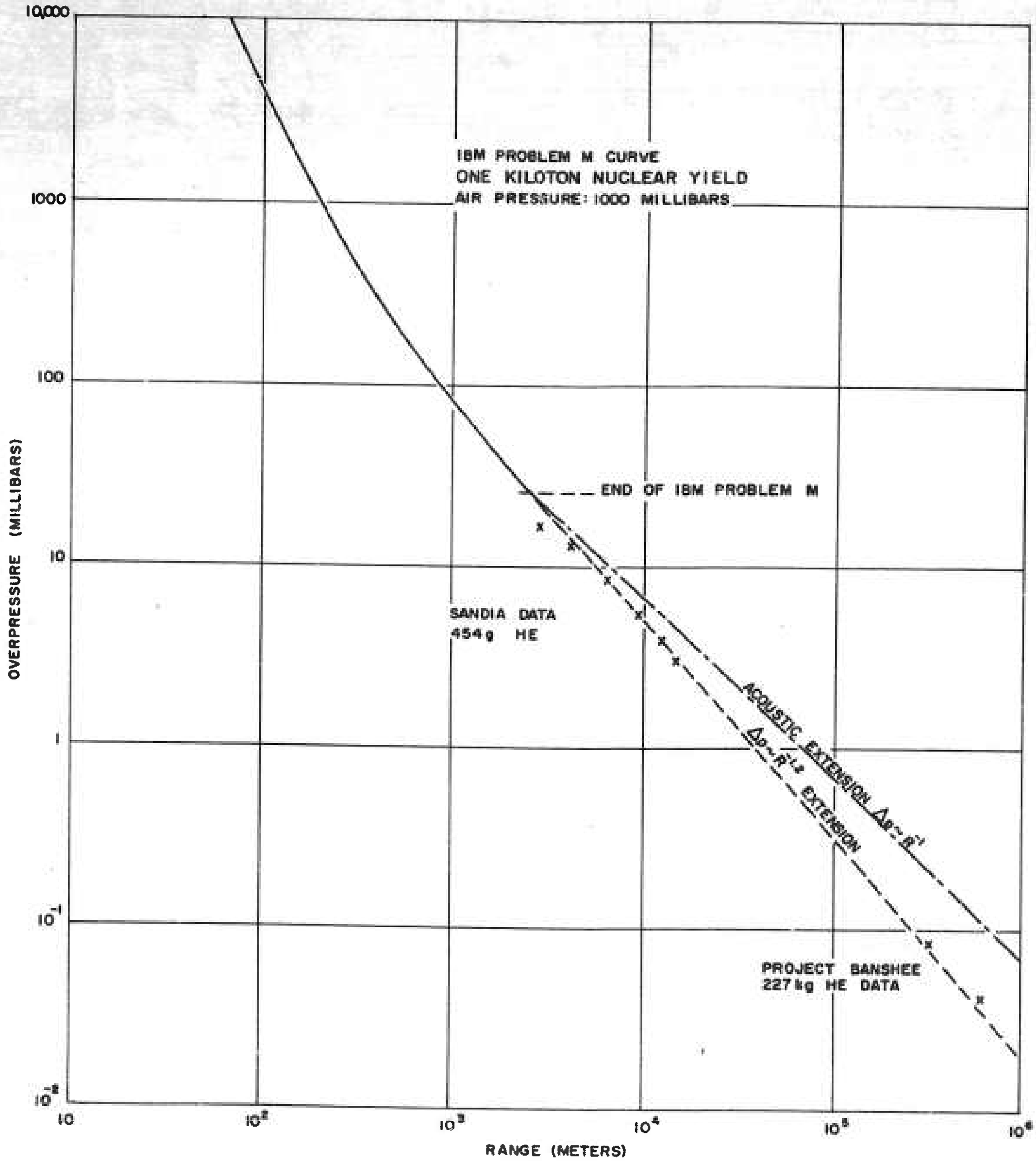

Figure 1.2 Standard explosive overpressure-distance curve

where W is yield, p is atmospheric pressure, unprimed quantities are standard values, and primed quantities are new values for specified conditions. In the extended low-pressure region where $\Delta p \sim R^{-1.2}$, it follows that at constant range,

$$\Delta p \sim W^{0.4}. \qquad (1.4)$$

Air-burst calibration shots were fired to show actual atmospheric propagation conditions as near to Danny Boy in space and time as operations would permit. Results could be scaled to predict pressures from Danny Boy if fired as a free air burst. Pressure amplitudes for Danny Boy, divided by this scaled prediction, would give the air-blast transmission coefficient.

Calibration shots were 1.2-ton HE burst 4.56 meters above ground. At this scaled height of burst, Mach stem effects cause blast overpressures which appear to have come from 1.76 W yield. This has been determined in Sandia HE experiments scaled by Vortman and Shreve (Reference 11) to 6.1 meters from 454-gram HE. Measurements at 190 km from 2.5-ton HE shots at Sandia in 1961 verify that close-in height-of-burst effects are propagated to large distances (Reference 12).

Predicted overpressure-distance for calibration shots on Danny Boy is then scaled by reducing standard overpressures to local ambient Area 18 atmospheric pressure (880.8 mb) or

$$\Delta p' = 0.8808\ \Delta p. \qquad (1.5)$$

Scaled ranges are obtained, assuming that 1-ton HE is equivalent to 2-ton nuclear in blast production, by

$$R_C' = R\left[(2)(1.76)(1.2)(1000)/(1000)(880.8)\right]^{1/3}$$
$$= 0.1683\ R. \qquad (1.6)$$

For Danny Boy, reported to have given a 430-ton nuclear yield, free air burst would have scaled pressures from Eq. 1.5 and distances scaled by

$$R_D' = R\left[(430)(1000)/(1000)(880.8)\right]^{1/3} = 0.786\ R. \qquad (1.7)$$

Free air-burst overpressure-distance curves for both the calibration shot and Danny Boy are shown in Figure 1.3, for the ranges covered by the microbarograph measurements.

Two alternative assumptions were considered in predicting actual Danny Boy air-blast pressures. First assume that nuclear devices burst underground would produce waves equal to those of HE bursts of the same yield. This follows from the concept that the radiant energy from an underground nuclear burst cannot escape. In air bursts this energy does escape to leave only half of the total yield available for shock formation. Danny Boy burial at 33.5 meters would thus be at a

scaled depth-of-burst of 1.158 λ $\left(1\lambda = 1 \text{ ft}/(\text{lb HE})^{1/3} \approx 3.8\text{m}/(\text{ton HE})^{1/3}\right)$. Reference to Figure 1.1 at 10^4 meters, shows that the Scooter air blast was about 2.2 times what would have been predicted from Stagecoach data. Buckboard transmissions interpolate for 1.158 λ to about 0.175; multiplication by the yield effect of Scooter (for comparable Danny Boy yield) gives a transmission prediction of 0.39. This gives the dashed pressure-distance curve in Figure 1.3 labelled 100-percent yield factor, for a Danny Boy prediction.

A second assumption may be made, namely, that nuclear burst effects are equivalent to those from half the stated yield in HE. Obviously, losses cannot be attributed to radiations. There are, however, mechanisms such as rock vaporization, lack of gaseous mass to push out an explosion wave and crater, etc., which may be used to explain the losses. No further explanation is appropriate here. In this case, burst would have been at 1.457 λ, where interpolation from Buckboard shows a transmission factor of 0.097 and the Scooter-to-Stagecoach yield effect raises the predicted transmission factor for Danny Boy to 0.215.

These predictions show that at nearly constant ranges, Danny Boy pressures would have 2.45 (assumption 1) or 1.35 (assumption 2) times the amplitudes recorded from HE calibration shots.

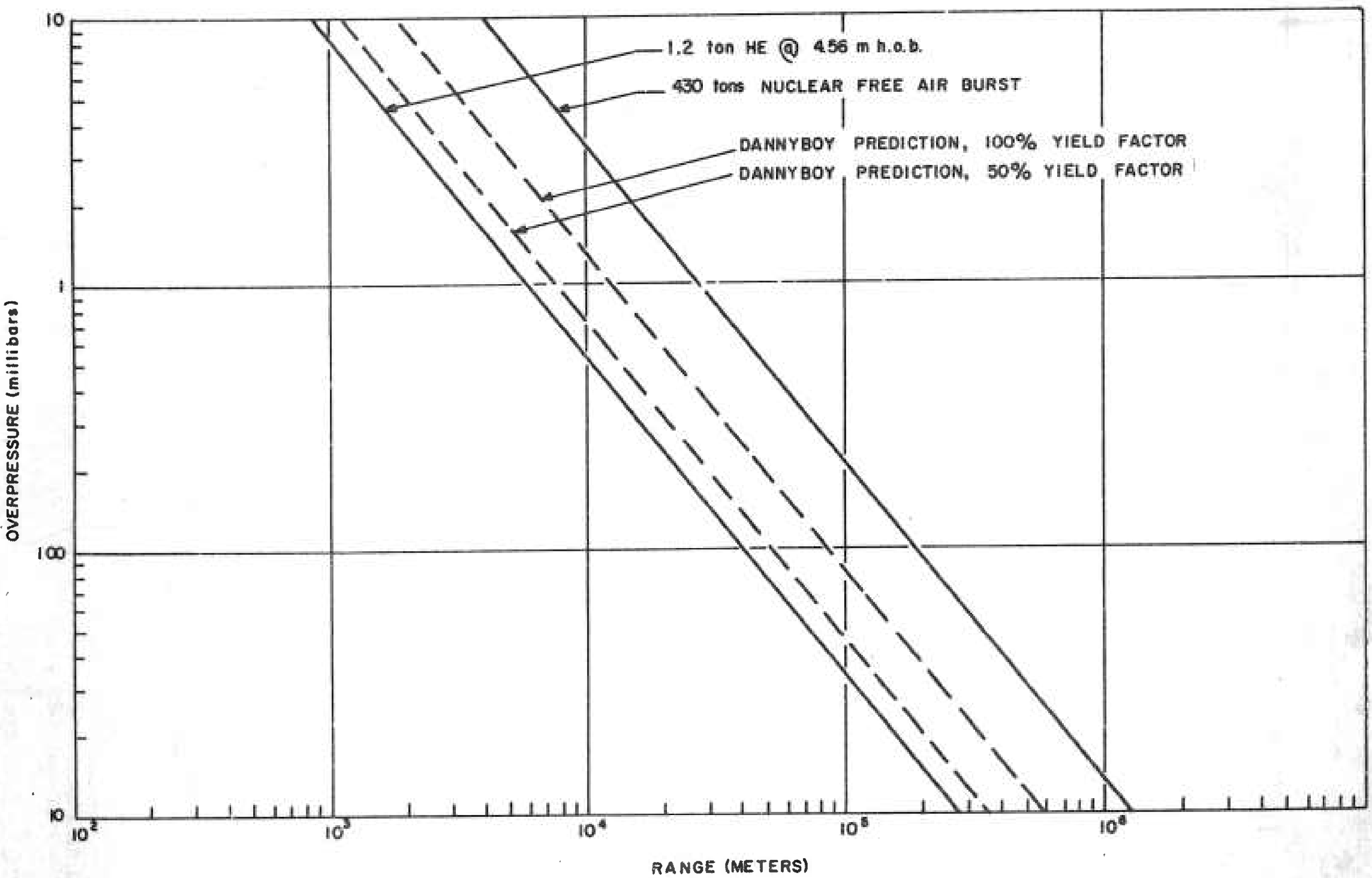

Figure 1.3 Danny Boy overpressure-distance predictions

CHAPTER 2

PROCEDURE

2.1 SHOT PARTICIPATION

Nine microbarograph stations were operated on Danny Boy. Two operated near 7- and 16-km ranges from surface zero to get data on the transmission coefficient transition between small close-in values and higher factors generally observed at great distance where the signal is carried by ozonosphere sound ducting. A station recorded at NTS CP-1 (Main Control Point) in Yucca Pass, only because equipment, communications, and an operator were there. A mountain ridge blocked sound propagation into CP-1, but a weak signal could diffract down to the station. Six off-site stations operated at Lund, Caliente, and Boulder City, Nevada, and Castlecliff, St. George, and Hurricane, Utah.

Locations of microbarograph project interest are shown in Table 2.1. Danny Boy surface zero, HE calibration shot points, and on-site microbarographs were positioned by survey in the Nevada State Coordinate System (NSCS) grid. Off-site station locations except Caliente had been located in latitude-longitude coordinates by at least third-order survey for previous experiments. The Caliente microbarograph location was estimated from a road map. All locations were converted to NSCS co-ordinates. Bearings and distances from each shot to each station are shown in the Table. The values for Lund, St. George, and Boulder City are

TABLE 2.1 MICROBAROGRAPH PROJECT OPERATING SITES AND SHOT-TO-STATION BEARINGS AND DISTANCES (METERS)

MB SITE	SHOT PT.	DANNY BOY	HE SITE #3 (H-2 Min.)	HE SITE #2 (H Hour)	HE SITE #1 (H+5 Min.)
		N261,989 E179,219	N258,102 E181,139	N258,052 E181,461	N258,358 E181,325
5-Mile	N264,721 E185,539 Z 1,605	066° 37' 6,886	033° 37' 7,949	031° 27' 7,819	033° 31' 7,633
Doe Sta.	N273,014 E191,144 Z 2,325	047° 15' 16,242	033° 52' 17,958	032° 55' 17,823	033° 49' 17,643
CP-1	N242,537 E207,024 Z 1,263	124° 58' 33,934	121° 01' 30,205	121° 15' 29,903	121° 37' 30,178
Lund	N456,918 E293,510 Z 1,699	031° 42' 229,109	030° 47' 231,437	030° 43' 231,316	030° 47' 231,122
Caliente (Est'd Loc'n)	N316,397 E343,843 Z 1,335	071° 43' 173,383	070° 17' 172,834	070° 14' 172,548	070° 21' 172,548
Castlecliff	N254,607 E398,785	091° 56' 219,693	090° 55' 217,275	090° 54' 217,352	090° 59' 217,494
St. George	N257,219 E425,980 Z 887	091° 06' 246,809	090° 12' 244,844	090° 12' 244,522	090° 16' 244,659
Hurricane	N267,970 E454,820	088° 45' 275,667	087° 56' 273,860	087° 55' 273,541	087° 59' 273,666
Boulder City	N135,048 E314,317 Z 750	133° 13' 185,379	132° 44' 181,325	132° 48' 181,054	132° 50' 181,362

earth-curvature corrected for the vector to NTS Station T-1 (full-scale shot point). Plane trigonometric adjustment was made to other Danny Boy locations. Curvature corrections were originally calculated from a 1955 first-order survey.

Planned calibration shots were to bracket Danny Boy at H-2 minutes and H+3 minutes. A reserve charge was emplaced in case Danny Boy was delayed after the first calibration shot was fired. Safety considerations dictated that this reserve charge be destroyed before post-shot re-entry, if it was not required. It was, therefore, scheduled to shoot at H+5 minutes. Some added information on signal variability with time would thus be recorded.

Each calibration charge was 1.2-ton uncased HE from surplus at NTS. Charges were made up of 16.3-kg blocks, stacked in an approximate cube. The total weight was the same as had been used for years in NTS blast propagation tests, equal to four U.S. Navy World-War II surplus depth charges. Aircraft operations and fire hazards in Area 18 prevented the firing of cased depth-charge blasts. Charges were stacked 4.56 meters above ground on light wooden platforms for height-of-burst magnification effects. Firing was triggered by hard-wire electrical signal from the Danny Boy firing-sequence control system at the Area 18 Forward Control Point.

Communications were planned to be carried on NTS Off-Site Net 12. Firing tones were to be sent at shot times, and an equipment turn-on signal was planned at

H-30 seconds. Preliminary voice reports on recording success were to be assembled at H+1 hour on this network. In event of radio communication failure, stations were instructed to use telephone communications wherever possible.

2.2 INSTRUMENTATION

Microbarograph sensors were Wiancko devices which have been used satisfactorily for years in recording distant air-blast waves from atomic and HE tests. They were designed to Sandia Corporation specifications and functioned properly according to laboratory tests (Reference 13). New transistorized amplifiers and timers were purchased in early 1960 from the Electronic Engineering Company, Santa Ana, California. Calibration tests show that pressure waves below 15-cps frequency and between 3-μb and 9-mb amplitudes are recorded accurately within ±20 percent for 85 percent of test points.

Stations at CP-1, St. George, and Boulder City were set up in available buildings. All other stations were mounted in carry-all type trucks as mobile units which could be moved from place to place, depending upon the particular experiment being recorded.

Rocket wind measurements were planned. However, radar equipment at the Tonopah Test Range (TTR) needed for chaff tracking had been moved to the Pacific, and the new TTR tracking system could not be made ready in time for use. Since this system was not operated, it will not be described.

2.3 DATA REQUIREMENTS

Recordings of pressure waves from Danny Boy and calibration shots were made at all microbarograph stations. Pressure-time Brush recorder pen traces (when successful) were obtained at a paper speed of 2.5 cm/sec and pressure scales which varied from 2 μb/mm to 240 μb/mm depending on station range from shots. Each set had been calibrated over static pressures ranging from 3 μb to 9 mb. Side-marking pens made 1-second time marks with distinctive pulses every 10 and 100 seconds. Shot-time radio tones were recorded on one of the pressure recording pens. When radio communications were poor or out, operators made time marks on records from wrist watches which had been synchronized with WWV-time or a telephoned count-down and hack from NTS.

Weather data were obtained from the U.S. Weather Bureau Research Station attached to the AEC-Las Vegas Area Office. Area 18 conditions of surface wind, temperature, and pressure were recorded. Detailed shot-time winds to 2.4 km MSL were measured by pilot-balloon techniques (PIBAL) and to 5.6 km MSL by radar-tracked balloon. Temperature, pressure, relative humidity, and winds were measured to 26.2 km MSL by the rawinsonde station at Yucca Flat.

CHAPTER 3

RESULTS

3.1 WEATHER OBSERVATIONS

Surface weather observations from Area 18 at shot time are tabulated in Table 3.1. Pilot-balloon winds near shot time and Area 18 rawinsonde observations are shown in Table 3.2. A radiosonde balloon was tracked from Yucca Flat Weather Station (UCC) to an altitude of 26.2 km where it burst. Winds, temperatures, pressures, and moisture data from this ascension are shown in Table 3.3. Other weather observations were made, but only those pertinent and necessary for sound-ray calculations are given here. Other information, if required, may be obtained from the U.S. Weather Bureau Research Station.

TABLE 3.1 AREA 18 SURFACE WEATHER OBSERVATIONS (1015 PST March 5, 1962)

Atmospheric Pressure.....	832 mb
Temperature.............	+9.7°C
Relative Humidity........	27% (from Yucca Raob)
Sky Condition...........	Overcast at 4 km MSL
Visibility..............	>25 km
Wind Direction (from)....	168° True
Wind Speed..............	6.2 m/sec

TABLE 3.2 UPPER AIR OBSERVATIONS, AREA 18

PIBAL WINDS

Altitude	Time: 1000 PST Direction/Speed	1025 PST Direction/Speed
km MSL	°T.N./meters per sec	°T.N./meters per sec
Surface	133/ 5.2	168/ 6.2
1.83	140/ 5.7	170/ 6.7
2.13	180/ 6.7	180/ 7.7
2.44	180/11.8	180/10.3
2.74		190/13.9
3.04		190/15.4
3.65		200/19.0
4.26		210/24.2

RAWINSONDE Time: 1025 PST

Height	Wind	Pressure	Temperature
km MSL	Deg/meters per sec	mb	°C
SFC 1.61	168/ 6.2	838	10.2
1.67	170/ 6.2	832	9.7
1.83	171/ 6.7	818	8.7
2.00	173/ 7.7	802	7.4
2.13	178/ 7.7	790	6.1
2.44	184/10.3	762	2.8
2.74	190/13.9	759	2.6
3.04	191/15.4	710	- 1.3
3.27	192/16.0	700	- 2.1
3.31	194/17.0	688	- 3.4
3.35	195/17.5	683	- 3.4
3.65	199/19.1	658	- 3.5
3.70	200/22.2	654	- 3.5
3.96	202/23.7	635	- 4.6
4.26	206/24.2	610	- 6.3

TABLE 3.3 RAWINSONDE REPORT

Upper Air Data
(Yucca Weather Station, 1015 PST, March 5, 1962

Height		Wind	Pressure	Temperature	Dew Point	Relative Humidity
km	MSL	Deg/ meters per second	mb	°C	°C	%
SFC	1.20	calm	881	6.9	- 2.8	50
	1.22	calm	877	6.9	- 3.4	48
	1.39	167/ 2.6	860	7.0	- 10.3	28
	1.49	167/ 1.5	850	6.3	- 11.3	27
	1.52	170/ 3.6	845	6.1	- 11.5	27
GZ	1.67	179/ 7.2	832	5.3	- 12.2	27
	1.83	181/ 7.7	815	4.3	- 13.0	27
	2.13	188/10.8	784	2.3	- 15.7	25
	2.44	189/13.9	757	0.3	- 18.9	22
	2.74	190/14.9	727	- 1.7	- 21.2	21
	2.88	196/11.3	716	- 2.4	- 21.8	21
	3.04	198/13.9	701	- 3.0	MB	MB
	3.04	198/14.4	700	- 3.0	MB	MB
	3.35	199/13.9	674	- 5.5	MB	MB
	3.54	192/15.5	657	- 7.5	- 25.6	22
	3.65	191/16.0	647	- 7.6	- 16.2	50
	3.70	191/17.0	644	- 7.7	- 14.5	58
	3.96	194/20.1	624	- 7.5	- 11.7	72
	3.97	194/20.1	623	- 7.5	- 11.3	74
	4.26	199/22.7	598	- 9.1	- 12.5	76
	4.57	200/26.3	576	- 10.7	- 13.8	78
	4.61	202/26.3	572	- 10.9	- 14.0	78
	4.87	211/25.8	552	- 12.6	- 15.6	78
	5.18	216/23.7	532	- 14.5	- 17.6	77
	5.48	225/25.8	511	- 16.5	- 19.8	76
	5.64	228/26.3	500	- 17.6	- 20.8	76
	5.79	230/25.8	491	- 18.5	- 22.1	74
	6.09	231/23.2	470	- 20.7	- 24.1	74
	6.21	231/21.1	462	- 21.4	- 24.8	74
	6.39	230/20.6	452	- 22.6	- 26.3	72
	6.70	232/23.7	433	- 24.6	- 28.5	70
	7.00	229/24.7	409	- 27.4	- 31.5	68

TABLE 3.3 (cont.)

Height	Wind	Pressure	Temperature	Dew Point	Relative Humidity
km MSL	Deg/ meters per second	mb	°C	°C	%
7.27	225/25.2	400	- 28.5	- 32.7	67
7.31	223/25.2	398	- 28.8	- 33.3	65
7.61	220/26.9	380	- 31.5	- 36.4	62
7.92	220/28.3	366	- 33.9	- 39.1	60
8.22	223/28.3	350	- 36.3	- 41.5	59
8.25	222/28.3	348	- 36.8	- 42.0	59
8.53	224/28.3	334	- 39.5	- 44.5	59
8.58	224/27.8	332	- 40.0	- 45.0	59
8.83	225/27.8	319	- 42.6	-	-
9.13	226/27.8	306	- 45.1	-	-
9.26	225/28.3	300	- 46.3	-	-
9.97	230/31.4	269	- 53.2	-	-
10.33	238/32.4	254	- 55.9	-	-
10.44	240/32.4	250	- 56.1	-	-
10.66	242/34.0	242	- 56.8	-	-
11.74	243/36.1	203	- 59.9	-	-
11.85	244/36.1	200	- 59.8	-	-
12.18	243/34.0	189	- 59.4	-	-
13.39	244/29.9	156	- 58.5	-	-
13.65	244/30.4	150	- 58.6	-	-
13.70	244/29.9	148	- 58.6	-	-
14.14	243/30.9	139	- 58.7	-	-
14.37	243/33.0	134	- 59.9	-	-
14.90	244/32.4	123	- 59.9	-	-
15.22	248/30.4	115	- 61.6	-	-
15.47	251/28.3	112	- 63.0	-	-
16.16	264/24.7	100	- 64.0	-	-
16.75	255/22.7	91	- 64.8	-	-
17.67	252/20.1	78	- 66.0	-	-
18.17	258/14.9	72	- 62.3	-	-
18.27	260/14.4	71	- 62.4	-	-
19.70	276/17.5	56	- 64.7	-	-
19.79	275/18.5	55	- 63.5	-	-
20.05	278/18.0	53	- 61.5	-	-
20.40	283/16.0	50	- 62.0	-	-
20.66	288/13.4	48	- 62.3	-	-
21.31	294/12.9	43	- 60.9	-	-

TABLE 3.3 (cont.)

Height	Wind	Pressure	Temperature	Dew Point	Relative Humidity
km MSL	Deg/ meters per second	mb	°C	°C	%
22.29	296/14.9	37	- 58.9	-	-
22.84	293/16.0	34	- 57.3	-	-
23.60	292/14.9	30	- 55.1	-	-
24.36	294/14.4	27	- 53.0	-	-
25.88	290/15.5	21	- 48.9	-	-
26.23	-	20	- 48.0	-	-

3.2 BLAST PRESSURE MEASUREMENTS

Danny Boy was fired at 1015 PST, after a 15-minute delay announced within the last pre-shot hour. The H-2 minute calibration shot fired on schedule, and the firing signal was transmitted on Net 12 Radio. The H-30 second radio tone was sent out on schedule. At Danny Boy firing, no radio tone was transmitted. Also, for a yet undetermined reason, the calibration shot scheduled for H+3 minutes was fired at zero time; consequently, a firing signal was transmitted at H+3 minutes but no shot fired. At H+5 minutes, the last calibration shot fired, but no firing signal was transmitted to Net 12.

During the pre-shot night, Highland Peak radio relay station broke down, so off-site stations in the northeast and east lost radio contact. The 15-minute delay in firing could not be telephoned to some remote

sites. Each station, however, did manage to be "on" at signal arrival times. At Castlecliff and Hurricane, local winds caused ambient noise that obscured any signal which might have been recorded. The operator at Caliente had equipment troubles which were cured too late for recording when he thought signals were to arrive. However, the station was running at the correct time of arrival of the actual shots, and the recording showed readable deflections. The operator did not, however, have a sufficiently accurate time base to establish whether the recorded signals propagated in a troposphere wind jet duct or the ozonosphere sound duct. At present, it is believed the records were of ozonosphere-ducted waves.

Recording at Lund was made with a wrist-watch time base, and the 1-second marks appeared to have some nonlinear errors. Lacking precise timing marks, it is thus impossible to positively identify and separate the Danny Boy signal from (a) an ozonosphere duct signal from the H-2 minute calibration shot, or (b) troposphere and ozonosphere signals from the HE shot at zero time.

Good records were obtained from all shots by the St. George station. Ambient wind noise varied only from 2- to 6-μb amplitudes. A troposphere duct signal was recorded, followed later by two to three bursts of noise channeled by the ozonosphere. Signal correlations between Danny Boy and the H-2 and H+0 (different distance) minute shots are good. At H+5 minutes the

ozonosphere-signal record pattern had changed appreciably, and no troposphere signal could be detected.

At Boulder City, the first HE shot produced a good signal record from ozonosphere propagation and a possible troposphere-ducted signal. No troposphere signal was discernible from Danny Boy or the H+0 HE shot because of temporary gusty wind noises. Clear ozonosphere signals were recorded from both Danny Boy and the H+0 HE shot. The HE shot at H+5 minutes gave a possible weak troposphere signal and a good ozonosphere signal. Boulder City records are shown as a sample in Figure 3.1.

Good records were made of all shots at the Area 18 and Doe stations. Weak but readable signals were recorded at CP-1.

All pressure measurements, including tentative BRL close-in data, are plotted against the distance coordinate in Figure 3.2. All Danny Boy pressures fall well below the curve for HE calibration shots, where reference to Figure 1.3 shows that larger pressures were expected. Records from HE shots fall reasonably close to the curve predicted for homogeneous atmosphere transmission. The amount by which Danny Boy data fell below HE calibration shot data appears to decrease with distance, generally confirming the increased transmissivity at long range shown in Figure 1.1

Calculation of transmission factors will not be made until final radio-chemical yield values are released for Danny Boy. It appears now that either

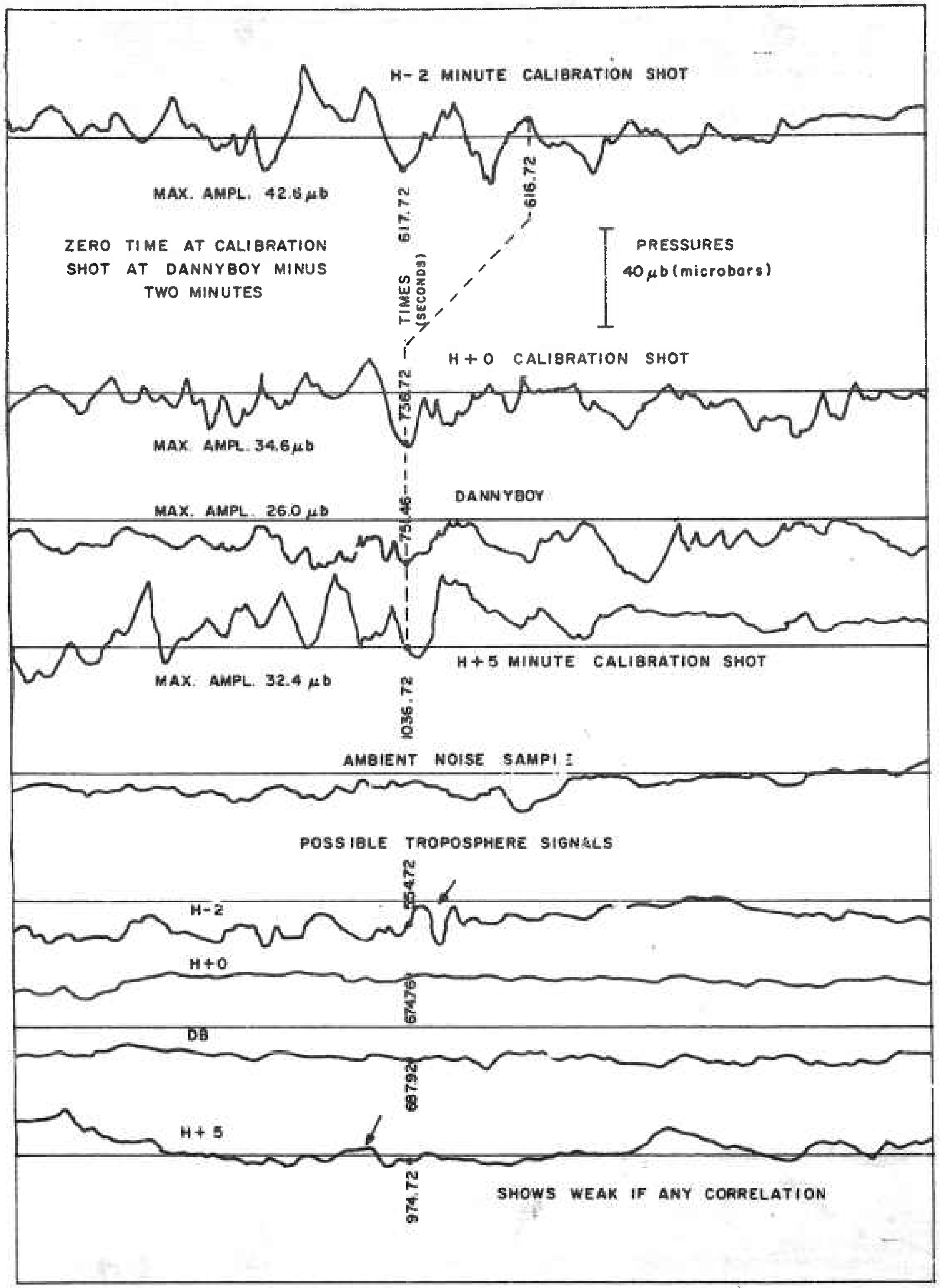

Figure 3.1 Danny Boy ozonosphere signals,
Boulder City, Nevada

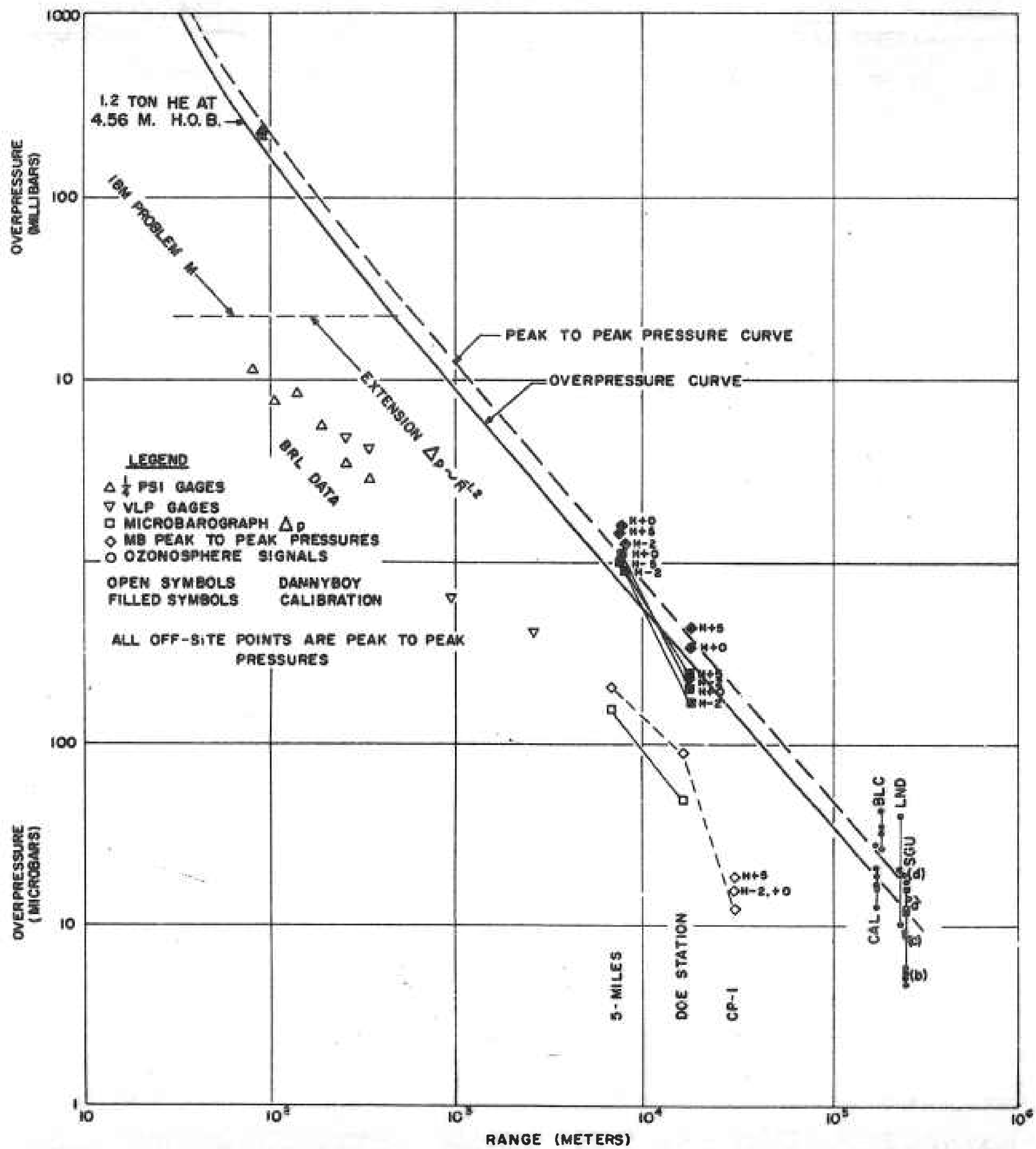

Figure 3.2 Danny Boy microbarograph data

430-tons is too large a yield figure for Danny Boy or that air-blast transmissions from underground nuclear bursts are smaller than from equivalent-yield HE.

Ray calculations have been completed on the CDC-1604 computer, using weather data for the troposphere obtained from the Weather Bureau. Since no rocket winds were measured, no ozonosphere ray calculations could be made. Pattern plots from a typical calculation, one toward St. George, are shown for ray paths, pressures related to the standard curve, and mean travel speed (ground distance divided by arrival time) in Figure 3.3. A scale is shown to indicate that recorded troposphere signals followed 4, 5, or 6 atmospheric-ray path lengths to St. George and were thus reflected by ground 3, 4, or 5 times.

Other calculations showed inversion-type ducting to 4.6 km above ground; the signals were carried northeast toward the 5-mile, Doe, and Lund stations. Complex ducting was calculated toward Caliente, with a shallow complex duct beginning at 2.4 km and extending to 4.0 km and another at higher altitude extending from 5.2 to 5.6 km MSL. Calculation showed no ducting toward Boulder City in the southeast.

Ozonosphere wind information may be available from Meteorological Rocket Network firings at Point Mugu, California, or White Sands Missile Range, New Mexico (Reference 14). These sources will be checked, and if reasonable values for ozonosphere winds over Danny Boy can be estimated, then ozonosphere sound ducting calculations will be made at a later date.

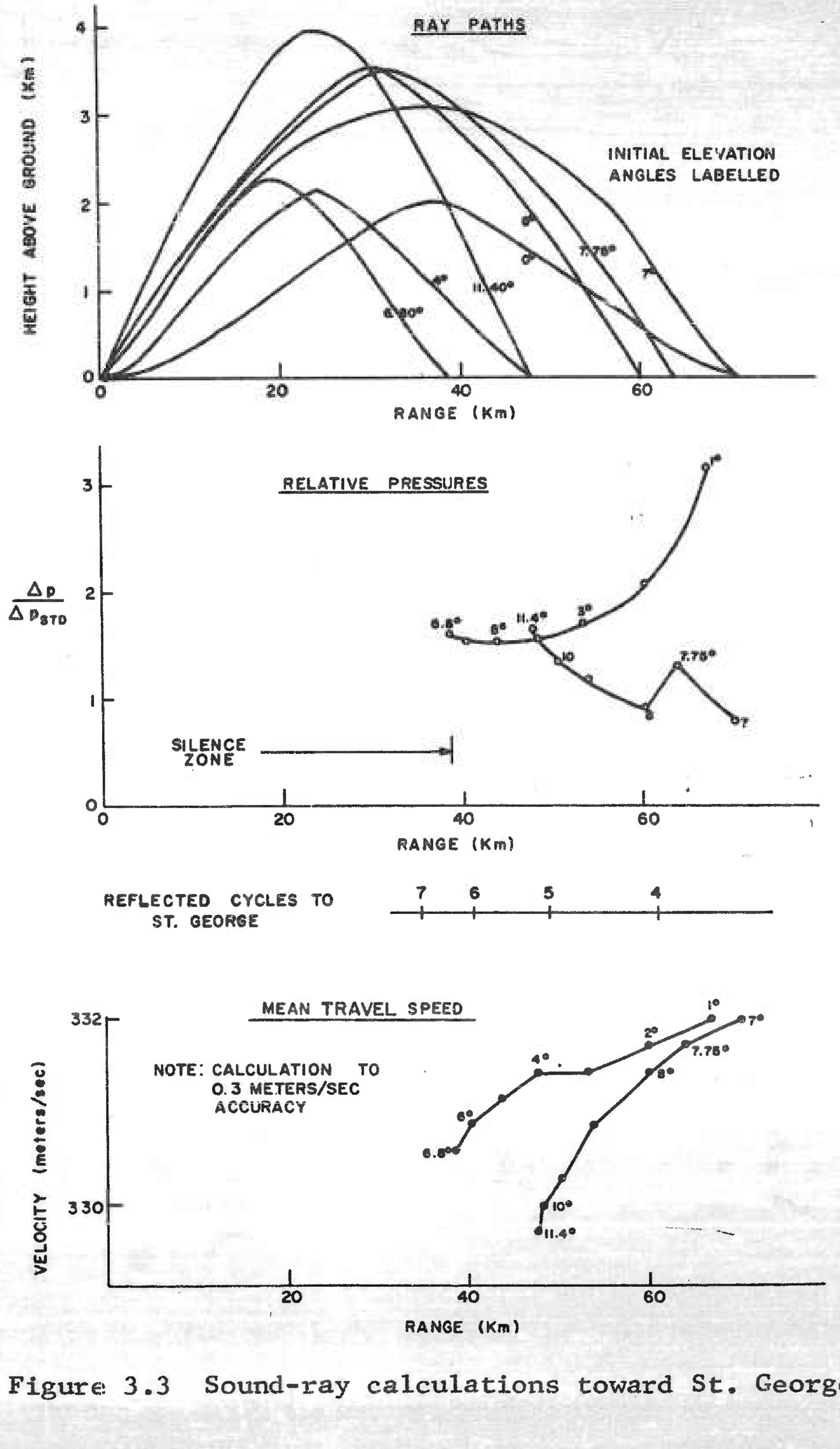

Figure 3.3 Sound-ray calculations toward St. George

CHAPTER 4

DISCUSSION AND TENTATIVE CONCLUSIONS

Because of (1) a partial off-site communications failure and consequent uncertain signal timing and (2) inadvertent simultaneous firing of an HE calibration shot at Danny Boy shot time, recorded signal identification is difficult or impossible at some stations. Ambient wind noise also made measurement impossible at two stations. These conditions appreciably cut the hoped-for number of signal correlation points. Because of time and space variations in atmospheric propagations, transmission factors will probably be determined to only with ±30 percent from the clear and usable off-site signal recordings which were made.

Danny Boy air-blast pressures, both close-in and far-out, were appreciably smaller than expected from experience with buried HE. This may be attributable to either (1) a nuclear blast efficiency even smaller, compared to HE, than that found in free air bursts or (2) a final value for radio-chemical yield below that reported from early air-sampling measurements.

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BOEING	The Boeing Company, Aero-Space Division, Seattle Attn: R. H. Carlson
EG&G	Edgerton, Germeshausen, and Grier, Inc., Boston, Las Vegas, and Santa Barbara
ERDL	U. S. Army Engineer Research & Development Laboratory, Fort Belvoir
LRL	Lawrence Radiation Laboratory, Livermore
NDL	U. S. Army Chemical Corps., Nuclear Defense Laboratory, Maryland
REECo	Reynolds Electrical and Engineering Co., Las Vegas
SC	Sandia Corporation, Albuquerque
SRI	Stanford Research Institute, Menlo Park
UCLA	University of California, Los Angeles
USC&GS	Coast and Geodetic Survey, Washington, D. C. and Las Vegas
USPHS	U. S. Public Health Service, Las Vegas
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